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WASTE HEAT RECUPERATOR

MANITOBA ROLLING MILLS

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MANITOBA/CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources — oil and natural gas — are becoming less accessible and more costly. However, Canada is well-endowed with renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of Manitoba and Canada entered into a Conservation and Renewable Energy Demonstration Agreement which was signed May 9, 1980 and terminated March 31, 1984. The Agreement was dedicated to the development and demonstration of conservation and renewable energy technologies. Equally cost-shared by the provincial and federal governments, the program had a total budget of $18-million.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology.
- To provide opportunities for the commercial application of the technologies within Manitoba.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

Opinions contained in this report are those of the author(s) and are not necessarily those of the Manitoba Department of Energy and Mines, or Energy, Mines and Resources Canada.

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MANITOBA ROLLING MILLS
A Unit of AMCA International Limited

REHEAT FURNACE MODIFICATIONS

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1.0 EXECUTIVE SUMMARY

Under the Canada/Manitoba Conservation and Renewable Energy Demonstration Agreement (CREDA), Manitoba Rolling Mills received funding to offset a portion of the capital costs for the addition of a waste heat recuperator to a natural gas fired billet reheat furnace at its rolling mill located in Selkirk, Manitoba.

A preliminary engineering and feasibility study was done by Scouten Mitchell Sigurdson and Associates Limited of Winnipeg, Manitoba and Cogeneration Associates Limited of Toronto, Ontario. Detailed engineering, supply and construction was completed by Lee Wilson, Toronto, Ontario.

In the operation of a steel rolling mill, excess heat is generated by the process only while operating, therefore the use of recovered heat is restricted to a few process-related possibilities such as preheating the billets or preheating the combustion air for the furnace.

Several alternatives for energy conservation were considered, including electrical induction heating, prior to selecting a waste heat recuperator designed to preheat the combustion air to 900°F before entering the billet preheat furnace burners. Studies of the existing furnace indicated that approximately 50% of the heat in the fuel was lost due to high temperature stack gases. The recuperator, a 2-pass air-to-air tube type heat exchanger, was installed adjacent to the existing furnace. The old waste gas stack was blocked off and the hot gases re-directed by ductwork so that they passed through the recuperator and then discharged to the atmosphere through an ejector fan stack.

The preheat combustion air is distributed to the roof burner system of the reheat furnace via insulated ductwork.

Agreement was reached with the Canada/Manitoba governments on the project in April, 1984 and construction began in August, 1984. Final tie-in and commissioning was completed during the two week Christmas/New Year's period and start-up was January 7, 1985. The work was completed within the $1.5 million capital cost estimate.

This report summarizes the alternatives considered, the selection and specification of the waste heat recuperator system and controls, and the performance of the furnace in its initial eight weeks of operation.

The projected combined energy savings resulting from the addition of the recuperator and controls amounted to 31%. This would be equivalent to $576,000 per year at present natural gas prices and a 200,000 ton year production rate.

At the time of this writing, overall energy consumption has been reduced from 2.33 million BTU's/ton to 1.61 million BTU's/ton, a saving of approximately 31%. Further work on furnace control optimization is in progress and it is anticipated that further savings in energy consumption will be achieved.

Production improvements have also resulted from the conservation program. The billets are more uniformly heated, with less scale formation and capacity has been increased beyond the previous 80 tons/hour maximum.

A supplementary report on furnace energy savings will be prepared following completion of control modifications and implementation of a standardized operating practice.

1.0 SOMMAIRE

Dans le cadre du Programme (Canada-Manitoba) de démonstration des énergies renouvelables et des économies d'énergie (PDÉRÉÉ), la société Manitoba Rolling Mills a reçu une subvention visant à compenser partiellement les dépenses en capital consenties pour l'installation d'un récupérateur de chaleur perdue sur un four à réchauffer les lingots, alimenté au gaz naturel, situé à l'aciérie de Selkirk, au Manitoba.

Les études techniques préliminaires et les études de faisabilité ont été entreprises par Scouten Mitchell Sigurdson and Associates Limited de Winnipeg et Manitoba and Cogeneration Associates de Toronto (Ontario). Les études techniques définitives, l'approvisionnement et la construction ont été confiés à Lee Wilson de Toronto (Ontario).

Les procédés qui entrent dans l'exploitation d'une aciérie se soldent par la production d'un excès de chaleur qui ne se manifeste que dans la phase active de l'opération. La chaleur ainsi récupérée ne peut donc être utilisée que pour quelques opérations, comme le préchauffage de l'air de combustion à 900 °F avant l'admission dans les brûleurs du four de préchauffage des lingots. Les études portant sur les brûleurs existants ont démontré qu'environ 50 % de la puissance calorifique du combustible était perdue à cause des températures élevées des gaz dans les cheminées. L'ancienne cheminée d'évacuation des gaz brûlés a été bouchée et les gaz chauds ont été recanalisés de façon à traverser le récupérateur avant d'être évacués dans l'atmosphère par une cheminée à ventilateur d'éjection.

L'air de combustion préchauffé était acheminé par canalisations isolées aux brûleurs supérieurs du four de réchauffage.

L'entente entre les gouvernements du Manitoba et du Canada a été conclue en avril 1984 et les travaux de construction ont débuté en août 1984. Les raccordements définitifs et les derniers ajustements ont été terminés entre Noël et le Nouvel An et le démarrage s'est effectué le 7 janvier 1985. Les dépenses en capital n'ont pas dépassé les prévisions se chiffrant à 1,5 million de dollars.

Le présent rapport expose de façon résumée les diverses options envisagées, le choix et les caractéristiques techniques du système de récupération de la chaleur perdue et des commandes, ainsi que le rendement du four pendant les huit premières semaines d'exploitation.

L'installation du récupérateur et des systèmes de commande devait se traduire par une économie d'énergie de 13 %, soit 576 000 $ par an au prix actuel du gaz naturel, à un niveau de production annuel de 200 000 tonnes.

À l'heure actuelle, la consommation globale d'énergie est passée de 2,33 millions de BTU/tonne à 1,73 million de BTU/tonne, soit une économie d'environ 25 %. D'autres travaux visant à optimiser le rendement du four se poursuivent, et l'on s'attend à ce que l'on puisse se rapprocher du niveau d'économie prévu à l'origine.

Un autre rapport portant sur les économies d'énergie réalisées sera rédigé à l'issue des modifications qui doivent être apportées au système de commande et de la mise en oeuvre de méthodes d'exploitation normalisées.

2.0 INTRODUCTION

During 1982-1983, Cogeneration Associates/Scouten Mitchell Sigurdson prepared a report under the Conservation and Renewable Energy Demonstration Agreement (CREDA), on waste heat recovery applications in Manitoba. Included in this report was the billet reheat furnace at Manitoba Rolling Mills Selkirk steel mill.

Subsequent to this, Manitoba Rolling Mills and the Department of Energy and Mines Manitoba conducted a shared cost feasibility study into the alternatives and feasibility of waste heat recovery versus substitution of hydro electric energy for natural gas for reheating of billets. The recommendation was to proceed with a waste heat recuperator and microprocessor based control system. The agreement was signed in April, 1984 under the Conservation and Renewable Energy Demonstration Agreement (CREDA). Total capital costs were estimated at $1,447,776 including CREDA funding of $516,858.

Lee Wilson Engineering of Toronto, Ontario designed, supplied and installed the system, with a Thermal Transfer heat exchanger and Honeywell microprocessor based control system. The heat recuperator is a 2-pass tube type air-to-air heat exchanger which preheats the combustion air for the natural gas fired furnace to 900°F, using heat recovered from the furnace exhaust gases. It was estimated that prior to installation, approximately 50% of the heat was lost to high stack gas temperatures and that a 31% reduction in energy consumption could be achieved with the recuperator. At an annual production rate of 200,000 tons, savings of $576,000 were projected.

Site construction began in August, 1984 with the tie-in of the system completed during the Christmas/New Year's period. The furnace with the recuperator and control system was commissioned on January 7, 1985.

3.0 BACKGROUND

The rolling mill at Selkirk, Manitoba was commissioned in 1976 as a state-of-the-art reversing rougher and 14-stand continuous bar mill. Due to then current and projected prices of natural gas, recuperators were not considered economical, and in fact, not one comparable reheat furnace in Canada had such a unit until this installation. Manitoba Rolling Mills produces standard bars and structural shapes and a wide range of special shapes in both merchant and special bar quality. Mill capacity exceeds 250,000 annual tons, but for the past two years has operated in the 200,000-220,000, ton range.

Historically, gas consumption has averaged approximately 2.35 MCF/ton, representing an annual fuel bill of approximately $2,000,000. With continual price escalation anticipated, and the need to maintain a competitive market position, it was obvious the project was attractive. However, the retrofit of a waste heat recuperator to an existing furnace had not been attempted in Canada. Combined with a substantial production loss to install, it was essential to obtain CREDA assistance to offset the technical risks and costs.

3.1 ALTERNATIVES CONSIDERED

- Recuperator
- Unfired Preheat Section
- Induction Heating
- Combustion Control System Upgrading
- Furnace Modifications; Charge and Discharge Ends
- Oxygen Enrichment

3.1.1 RECUPERATOR

Without heat recovery equipment, approximately 50% of the heat in the fuel is lost in the high temperature stack gases. Through the use of a recuperative heat exchanger, a portion of this heat can be recovered and used to preheat combustion air before entering the furnace, thereby reducing fuel requirements and increasing furnace heating efficiency.

It was proposed that the new recuperator be located outside the existing building, complete with a new combustion air fan and exhaust stack. This arrangement allowed the maximum amount of the conversion work to be completed prior to the actual changeover period.

The theoretical maximum fuel savings with a preheat temperature of 900°F were calculated to be 25.4% of the previous requirements for the same production rates of 42 tons per hour average.

The use of a preheat temperature of 600°F was also considered. The theoretical savings were calculated to be 18%.

The actual anticipated fuel savings were lower than the above noted percentages due to allowance for heat losses from ductwork and air leakage through openings in the furnace.

The actual fuel savings were estimated to be 22%, including an allowance for these heat losses. Applied to a previous fuel cost of $2,047,000 for a typical year, the anticipated cost savings were estimated to be $450,300.

The estimated total capital cost was $1,300,000. The annual maintenance costs were estimated at 2% of the total capital cost or $26,000. Annual savings would therefore be:

$$\$450,300 - \$26,000 = \$424,300$$

for a payback of 49 months (12% interest).

3.1.2 UNFIRED PREHEAT SECTION

An unfired preheat section would, in effect, be an extension of the furnace charge end. Billets would pass through this section before entering the first burner zone and would pick up heat from the hot products of combustion. The flue gasses would be cooled and a portion of the present flue gas heat losses would be recovered in the billets.

Interferences with the existing building structure required that this section be offset from the charge end of the furnace. This required additional mechanical handling equipment. Interferences with the normal operation of the billet crane would also cause problems.

Billet temperatures at the end of the preheat section were estimated at 300°F to 500°F. Average fuel savings were estimated to be 10%-12% for a cost saving of $200,000-$250,000 annually.

The capital cost was estimated at $1,537,000 and the payback exceeded sixteen years.

3.1.3 INDUCTION HEATING

From an economic point of view, the major potential attraction of an electric induction heating furnace would be the expected increase in heating efficiency that could be realized by the elimination of flue gas heat losses. The overall economics are determined by the relative cost of electric power and natural gas, the furnace heating efficiency and the capital cost.

The induction furnace would consist of a series of alternating current coils through which billets would be conveyed. Induced currents in the billets would provide the heating effect. Associated with the furnace would be transformers, frequency converters, capacitors, inductors, switching units and ground fault protection. A new building would be required, 270' x 65', to house the rather long furnace section.

Although there would be no stack gas losses, cooling water losses and radiation losses would total approximately 45%.

The estimated annual power cost was $2,285,000 based on the 1982 average power cost of 2.47¢/KWH.

The estimated capital cost was $10,577,000.

The operating cost of the induction furnace is higher than the present operating cost based on present and anticipated cost increases in electrical rates (and demand charges) and gas rates.

3.1.4 COMBUSTION CONTROL SYSTEM UPGRADING

In the original combustion control system gas flows followed air flows, which were adjusted to maintain zone temperature set points. This type of system results in excess air conditions during firing rate increases and low air conditions on firing rate decreases. Turndown ratios are not sufficient to allow the furnace to be held at a low temperature during Mill delays.

A new control system was proposed, based on a modern microprocessor controller which would provide fully cross limited combustion control, eg., gas flow follows air flow on firing rate increases and air flow follows gas flow on firing rate decreases; thus maintaining a more correct ratio. Turndown ratios are improved by more precise measurement of air and gas flows. Temperature profiles through the furnace can be adjusted to suit a particular production rate, thus ensuring that stack temperatures are maintained at an optimum low value.

Fuel savings were estimated at 12% or $245,000 per year based on decreases in stack gas losses (lower temperatures). Capital costs were estimated at $350,000-$400,000 including provisions for the following:

- Furnace pressure control
- Recuperator (temperature compensation and protection)
- Production rate based profile adjustment
- Oxygen trim control
- Data logging
- Recorders

3.1.5 FURNACE MODIFICATIONS

3.1.5.1 CHARGE END EXTENSION

The existing furnace is not equipped with a charge end door. A series of hanging screens are installed across the opening to reduce radiation losses from the hot refractory inside the furnace, and to reduce air infiltration or hot gas leakage. A 1.8m (6') extension of the furnace was proposed which would have provision for side charging of billets through a small side opening with a door.

This would reduce the above mentioned heat losses significantly. More importantly, the flue gas exit would be relocated to the end of the extension and ducted from there to the existing stack. Thus, the extension would act as a short unfired preheat section, and the flue gases would be expected to be cooled somewhat below present exit temperatures.

3.1.5.1 CHARGE END EXTENSION (Continued)

It was estimated that an overall fuel savings of 5% would be realistic for this option. Calculations are based on a computerized mathematical model of gas flow patterns and temperature profiles within the furnace. Radiation losses and leakage/infiltration losses would be essentially eliminated, and the stack temperature reduced by approximately 56°C (100°F).

Fuel savings on this basis would be in the order of $100,000 per year. Capital costs were estimated at $320,000 covering engineering, supply and installation of the required equipment. A contingency allowance of 10% to cover estimating errors brought the capital cost to $352,000.

Based on interest rates at 12%, the payback term would be sixty-five months.

3.1.5.2 DISCHARGE END EXTENSION

A similar extension was proposed for the discharge end of the furnace. In this case, an extension of 2.7m (9') was proposed and side discharge was included via a peel bar mechanism. A lifting frame was also included to receive the hot billet and feed it into the existing rolling line at a lower elevation.

Ten additional roof mounted burners were proposed to maintain temperature in the extended soak zone.

Because the discharge zone is presently equipped with a pneumatically operated door, the reduction in radiation and leakage losses would not be as significant as estimated for the extended charge end. Adding burners would imply some increased production capability, but would also allow a shift in heat release towards the discharge end of the furnace. Eg., it may be possible to turn down the Zone 1 burners while maintaining production rates. This would allow a somewhat lower flue gas temperature. In any case it would not be considered to be nearly as attractive as the charge end extension. The estimated capital cost was $465,000 which would increase to $511,500 with the inclusion of a 10% contingency allowance. Due to mechanical handling complications, this option was not considered to be attractive at this time.

3.1.6 OXYGEN ENRICHMENT

Oxygen enrichment was reviewed briefly as the subject had been under previous consideration by Manitoba Rolling Mills.

3.1.6 OXYGEN ENRICHMENT (Continued)

The benefits of oxygen enrichment are:

1. Increased flame temperature leading to higher heat transfer rates in the furnace.

2. Lower flue gas mass flows, resulting from reduced nitrogen from the air, therefore lower flue gas heat losses.

In combination, these benefits could be used to either increase production rates or improve heating efficiency.

An oxygen separation plant is located adjacent to the Manitoba Rolling Mills plant, and provides oxygen for other process requirements in the plant.

Two levels of oxygen enrichment were investigated, 2% and 35% enrichment.

Standard air contains 21% O2 and 79% N2 by volume. At 2% oxygen enrichment, oxygen is added to the combustion air to achieve a 23% O2/77% N2 mixture by volume. For the same fuel input, the air requirement will be lower than for standard air and the nitrogen losses in the stack gasses also lower.

Heat transfer rates to the billets would be higher and a reduction in stack gas temperature would be possible, subject to furnace geometry and burner arrangement.

For 2% O2 enrichment, Union Carbide claim 10%-20% fuel savings, Based on 10% savings, this would amount to 1.5 x 10^6 Nm^3 (54.2 x 10^6 $ft.^3$) natural gas or $204,000/year at current prices. Oxygen requirements would be 3.0 x 10^6 Nm^3 (107.3 x 10^6 $ft.^3$), costing $504,300 at current rates of 166Nm^3$ ($4.470/1,000 $ft.^3$). The capital cost estimated was $94,000.

Clearly the oxygen cost would have to be much lower and the fuel savings would have to be proven before such a scheme could be considered.

Surface Division of Midland Ross submitted a proposal for 35% oxygen enrichment, quoting savings of 20%-25%. The capital cost was estimated to be $750,000-$1,000,000 installed. Based on 25% savings, the annual gas consumption would be reduced to 11.5 Nm3 (406.5 x 106 ft.3) equivalent to a savings of $511,800. The oxygen required would be 18.1 Nm3 (640 x 106 ft.3) costing in excess of $3,000,000 per year. Again, the oxygen costs are much too high to produce a cost savings.

3.1.6 OXYGEN ENRICHMENT (Continued)

Other potential difficulties were identified with 02 enrichment including control problems and increased maintenance costs associated with burners and refractories operating at higher temperatures. With the higher levels of enrichment, increased billet scaling may also be a problem.

3.2 SUMMARY

Of the three original alternatives identified for study, the proposed induction heating furnace and unfired preheat section were not considered to be economically viable, due to high capital cost and relatively small (negative in the case of the induction furnace) energy cost savings. The recuperator proposal was considered to be the only one of these three alternatives having good overall economic viability. Payback was estimated to be just over four years, with estimated annual energy savings of 15.5%-22%, depending on combustion air preheat temperature chosen.

The proposed new control system as discussed in Section 4.1 was estimated to have an even faster payback of approximately two years, although the annual energy savings would be less than with the recuperator.

The third proposal which appeared to be attractive was the extension of the furnace charge end incorporating side billet entry. Based on a computer evaluation, a payback of approximately five years would be achieved, although the associated annual energy savings would be smaller than those resulting from either of the two above mentioned proposals.

Table 1 summarizes the capital costs, energy cost savings, overall annual operating cost savings and payback associated with each of these proposals.

3.2 SUMMARY (Continued)

Table 1 - Economic Summary

	Combustion Air ---Preheat Recuperator--- 316°C (600°F)	482°C (900°F)	Controls Auto Zone Temp.	Charge End Extension
Capital Cost	900,000	1,300,000	400,000	352,000
Energy Savings %	15.5	22.0	12.2	5.0
Energy Savings $	317,000	450,000	245,000	100,000
Maintenance Costs $	19,000	26,000	8,000	7,000
Annual Savings $	298,300	424,300	237,000	93,000
Payback (12% Interest) (Months)	51	49	24	65

Following detailed analysis of the three systems, the modifications were ranked according to their respective paybacks. The control system modifications were considered to be top priority, the recuperator next, and the charge end modification last. The charge end modification was considered to be a useful future modification if a higher tonnage rate was required from the furnace.

Cost sharing was eventually obtained for the control system and the 900°F recuperator only. Considering the minimal additional technical risks involved in the 900°F proposal over the 600°F proposal and the overriding expectation that gas prices would ultimately escalate in real terms, the 900°F proposal was selected, so as to maximize the energy conservation potential. The total energy savings resulting from the combination of 900°F air preheat recuperator and the control system was estimated to be 31% or $576,000/year at a 200,000 ton/year production rate. The charge end modifications were therefore deferred.

Final project capital costs were estimated at $1,500,000. The estimated payback for the combination chosen was therefore 3.3 years.

4.0 SYSTEM INSTALLATION

4.1 RECUPERATOR

Detailed discussions were pursued with Lee Wilson, Salem and Midland Ross - Superheater. All three firms submitted similar proposals, based on previous experience and using a recuperator supplied by Thermal Transfer. The proposals varied only in approach, detail and price.

The Lee Wilson proposal was selected due to price and their approach was the most conservative in terms of the modifications required. The recuperator provided the largest heat transfer area and the system was the least complex.

4.1.1 PRINCIPLE OF OPERATION

The recuperator works on a heat exchanger principle. Heat in the products of combustion exhausted from the furnace is transferred to incoming cold combustion air. The hot products of combustion are passed over steel tubes in the recuperator while the cold combustion air passes through the tubes. The heat is conducted from the products of combustion to the tubes and from the tubes to the combustion air. The heated combustion air is then delivered to the burners where it is mixed with natural gas and ignited.

The products of combustion that are exhausted from the recuperator contain considerably less waste heat than without the use of the recuperator.

4.1.2 DESCRIPTION

The Flow Diagram is shown in Figure 1.

Combustion air is drawn into the combustion air blower through an inlet silencer. Air pressure is controlled by electrically actuated inlet vanes installed on the blower unit controlled by a pressure signal on the hot side of the recuperator. The air from the blower passes through feeder ducts. The feeder ducts include venturis for flow measurement installed with straight runs of a minimum of 10 diameters upstream and 5 diameters downstream to ensure consistent air measurement. The feeder ducts connect to cross headers on top of the furnace and onto the burners. All ducts are either refractory lined (large ducts) or insulated (small ducts) to conserve energy and to protect personnel from high duct skin temperatures.

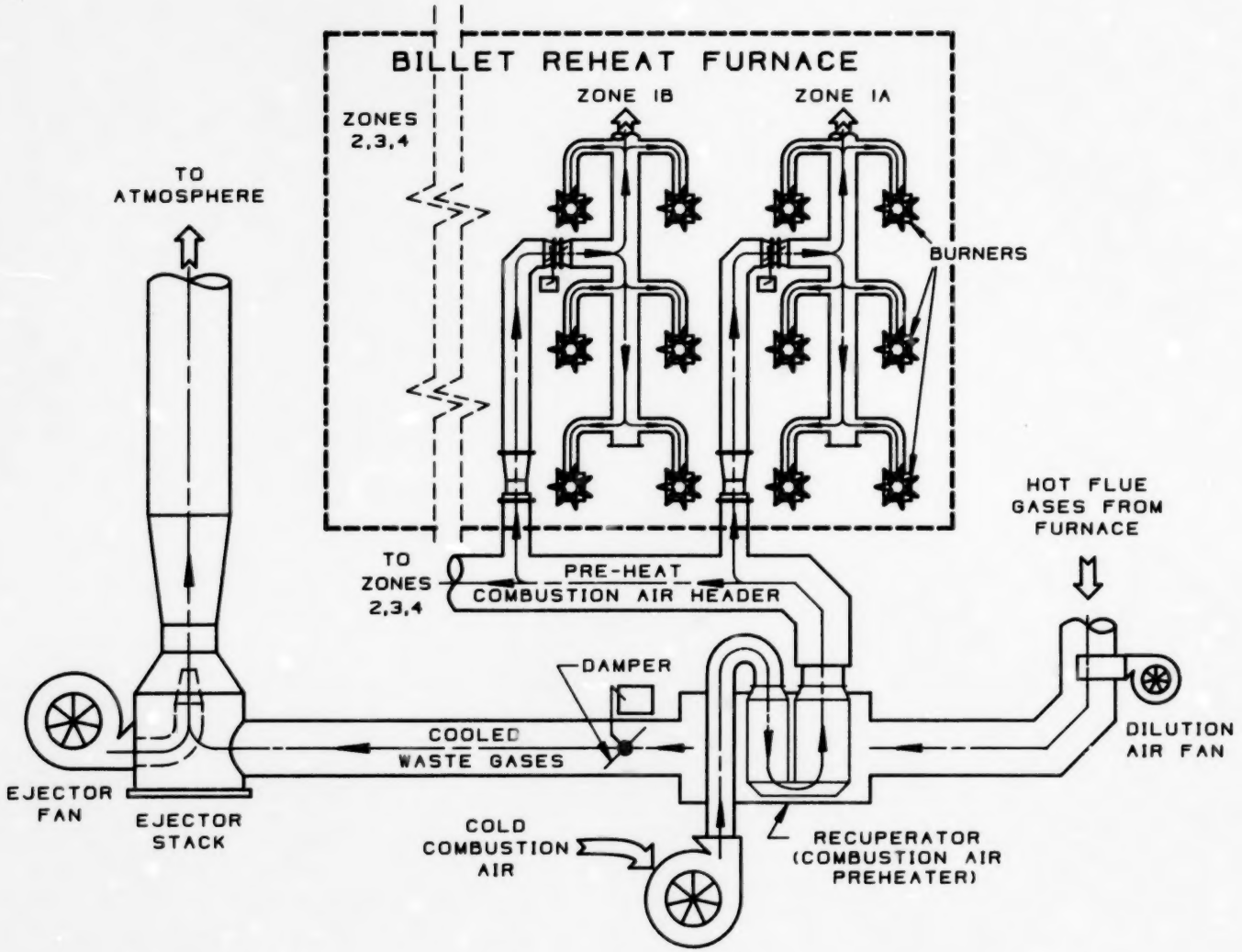


FIGURE -MANITOBA ROLLING MILLS REHEAT FURNACE
FLUE GAS HEAT RECUPERATOR SYSTEM

4.1.2 DESCRIPTION (Continued)

The original furnace pressure damper was sealed and a new flue gas outlet was cut in the end of the furnace exhaust plenum. A new duct carries the flue gas outside the furnace building to the recuperator where it passes over the recuperator tubes. A new furnace pressure damper, operated by an electrical actuator was installed on the recuperator outlet. A new fan-induced stack provided sufficient suction pressure to draw the waste products of combustion off the furnace through the recuperator.

A dilution air fan injects cold air into the flue gas to prevent over temperature conditions from damaging the recuperator and the burners.

An air seal fan and header arrangement was installed at the charge door to prevent the ingress of air.

4.2 CONTROL SYSTEM

Performance specifications were issued and quotations were received from the following:

- Moore Instruments Limited
- Foxboro Canada Incorporated
- Taylor Instruments
- Fisher Controls International
- Honeywell Limited
- G.E.C. Electrical Project Limited
- Bloom Engineering (Fischer & Porter)

All proposals would have provided adequate control. The proposals from G.E.C. and Bloom contain delay strategy features that are not included in the other proposals. Very little operating experience with delay strategy was available so it was considered advisable to purchase system capacity to handle the delay strategy but to postpone its implementation until the technology is proven. Delay strategy offers the potential to maximize furnace efficiency when anticipating a delay by reducing heat input until the latest possible time, reducing stack gas losses.

A Honeywell TDC 2000 was selected. The TDC 2000 is programmable and can be used effectively for data logging and programmed for delay strategy.

4.2.1 PRINCIPLE OF OPERATION

The Honeywell TDC 2000 is a distributed microprocessor based control system.

Lead-lag (cross limited) control is provided. On a firing rate increase, the air flow will increase first, followed by gas flow. On a firing rate decrease, gas will decrease first, followed by air. The controls are compensated for combustion air temperatures from ambient to 900°F. Combustion air pressure is regulated by an independent control loop.

The furnace is divided into four control zones, each zone having a thermocouple and a temperature controller. Zone 1A is slaved to Zone 1B for temperature control purposes but is equipped with a "maxon" valve and can be tripped off to provide a better turndown ratio for this zone under low rolling rate conditions. Air fuel ratio is maintained at a pre-determined value, usually 10% excess air except under rate change conditions when the air fuel ratio will increase slightly due to the lead-lag feature.

Furnace pressure is controlled to a pre-determined value, usually +.02 inches-water gauge.

Dilution air is added to the flue gas to protect the recuperator from over temperature and the burners from high combustion air temperature.

Alarms are logged and printed. Reports are available every hour, giving gas consumed since previous report, zone set points and actual temperatures, furnace pressure, and flue gas, waste gas and combustion air temperatures. A shift report is printed automatically at 07:00, 15:00 and 23:00 hours, giving the gas used per shift.

Space has been provided in the system for the following features:

- Automatic set point adjustment based on rolling rate.

- "Feed forward" control to anticipate size change, increased production rate.

- Automatic "hold" for reducing set points during interruptions of rolling.

- Trimming of air/fuel ratio based on measurement of stack or zone oxygen.

- Data logging, report generation.

- Interface to a supervisory computer.

4.2.2 DESCRIPTION

Combustion air pressure is monitored in the recuperator outlet header and is controlled by a "Dialatrol" and electric actuator- operated vanes on the combustion air fan inlet.

Combustion air temperature is measured by a thermocouple in the recuperator outlet header. The signal from the thermocouple feeds a strip recorder and provides a reference signal for the temperature compensation loop and the dilution fan control.

Gas pressure is maintained by the original North American regulation equipment.

Furnace pressure is measured by a very low pressure transmitter and is controlled by an electrically actuated damper between the recuperator and the stack.

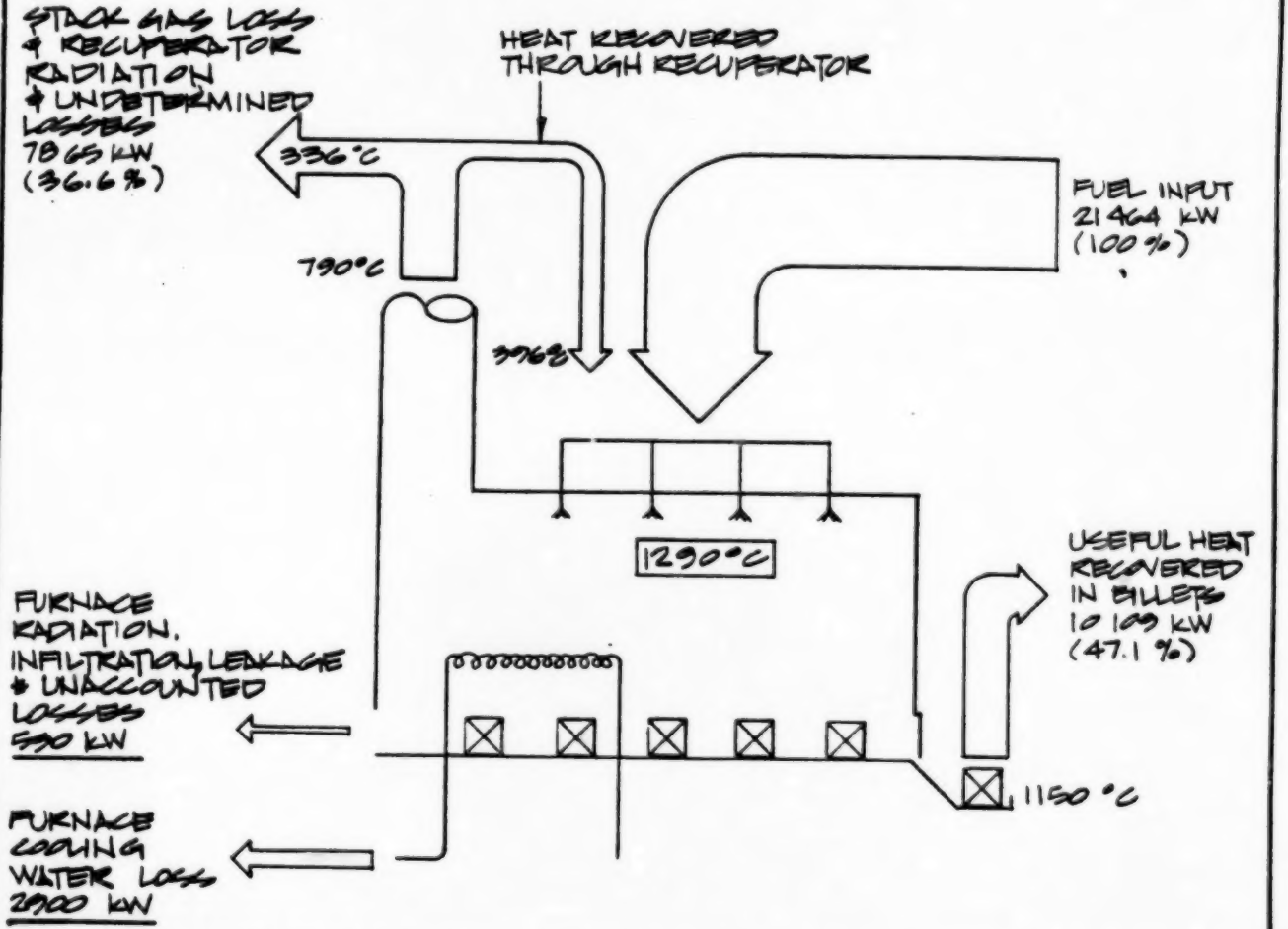
Combustion air flow for each zone is measured by a venturi and differential pressure transmitter and is controlled by an electrically actuated butterfly valve.

All transmitter signals are fed back to the TDC 2000 rack in substation No.1. This rack contains all controllers, signal converters, etc. Auto manual stations with analog temperature indicators and an LBOS (Local Batch Operators Station) are located within the roughing mill operators pulpit. From here, set point adjustments can be made for zone temperature, furnace pressure, and fuel air ratio. Details of process variables and control loop parameters can also be obtained.

5.0 RECUPERATOR AND CONTROL SYSTEM PERFORMANCE

Figure 2 shows the energy balance based on averaged, recorded data from a five day production run (February 25, 1985 to March 1, 1985). Average energy consumption has dropped by approximately 25% to 1.46 x 106 BTU/ton over this period, in comparison with the March, 1983 test run result of 1.95×10^6 BTU/ton. This result is consistent with longer term average savings projected from the February, 1985 records (1.73×10^6 BTU/ton), in comparison with the previous overall annual average of 2.33×10^6 BTU/ton, again approximately 25% savings. The later figures include lower average rolling rates and furnace holding time.

Detailed calculations supporting the Energy Balance Table (Figure 2) based on the February 25-March 1 production run are attached in the Appendix.



TOTAL FIXED FURNACE LOSSES = 3490 kW (16.3 %)

ENERGY BALANCE BASED ON
FEB 25 - MARCH 01 PRODUCTION RUN
@ 45.4 t/h (50 tons/h)

Scouten Mitchell Sigurdson Consulting Engineers Scouten Mitchell Sigurdson and Associates Limited 300–307 Smith Street, Winnipeg, Manitoba R3B 1L3 Telephone (204) 949-2111	MANITOBA ROLLING MILLS ENERGY RECOVERY PROJECT BILLET REHEAT FURNACE	FIGURE 2 Page 18 Drawn By: I.L.P. | Approved By: I.K. | Reference: File: 82-014-300 | Date: MARCH 1/83 | Detail Sheet:

6.0 ECONOMIC ANALYSIS

6.1 CAPITAL COST

The capital cost of the project was $1,500,000.

6.2 NET ENERGY COST

The projected net savings calculated for the first year of operation are:

Fuel Savings	$528,000
Less cost of additional electricity for auxiliary equipment	(20,000)
Less cost of additional maintenance	(30,000)
	$478,000

The components of the above calculation are explained in the following three sections:

6.2.1 FUEL SAVINGS

During the fiscal month of February, the gas usage was 1.73M MBTU/ton, a saving of 0.6M MBTU/ton over the gas usage for 1984.

The annualized fuel savings based on the 200,000 tons budgeted for 1985 would be 132,000M MBTU. Savings are costed at $4.00/MCF.

6.2.2 COST OF ELECTRICITY FOR AUXILIARY EQUIPMENT

The cost to run the auxiliary equipment on the original furnace was 300 KW/hour:	$ 60,000
The cost to run the auxiliary equipment on the modified furnace with the recuperator is 400 KW/hour:	$ 80,000
Net Increase per Annum:	$ 20,000

6.2.3 COST OF MAINTENANCE

Based on the estimate given in the Scouten Mitchell Sigurdson report, 2% x Capital Cost:	$ 30,000

6.3 SIMPLE PAYBACK

Based on the capital and installation cost of $1,500,000 and the projected net annual savings of $478,000, the simple payback of the recuperator would be:

$$\frac{\$1,500,000}{\$478,000} = 3.14 \text{ Years}$$

7.0 CONCLUSIONS

The waste heat recuperator and microprocessor based control system installed on the billet reheat furnace at Manitoba Rolling Mills is still in the commissioning and de-bugging stage. Projected energy savings of 750,000 BTU's/ton rolled have not yet been consistently achieved. We have achieved energy reduction of 600,000 BTU's/ton and there are indications that the original target will be exceeded, upon completion of control system modifications and the establishment of operating and delay strategies.

Billets are more uniformly heated with reduced scale formation which will ultimately improve finished product yield.

A follow-up report will be issued on furnace performance later in the year.

APPENDIX

ENERGY BALANCE BASED ON FEBRUARY 25 TO MARCH 1 PRODUCTION RUN

@ 45.4 TONNES/HOUR (50 TONS/HOUR)

1. FUEL INPUT RATE, AVERAGED OVER 118 HOURS:

Gas Consumed = 8,756 MCF @ 987 BTU/CF

$$= \frac{8{,}756 \times 1{,}000 \times 987}{118}$$

$$= 73.239 \times 10^6 \text{ BTU/Hour}$$

$$= 21{,}464 \text{ KW}$$

2. HEAT TO STEEL, AVERAGED OVER 118 HOURS:

Steel Produced = 5,901.6 Tons

Specific Heat of Steel = 0.165 BTU/lb./°F

Temperature Change °F = 2090°F (Average)

Heat Gain = $\frac{5{,}901.6 \times 2{,}000 \times .165 \times 2{,}090}{118}$

$$= 34.492 \times 10^6 \text{ BTU/Hour}$$

$$= 10{,}109 \text{ KW}$$

3. FIXED LOSSES FROM FURNACE:

Loss to Cooling Water = 2,000 USGPM x 8.342 $\frac{\text{lb.}}{\text{Gallon}}$ x (70.7°F - 60.8) x 60

$$= 9{,}910{,}000 \text{ BTU/Hour}$$

Radiation, Infiltration, Leakage, Unaccounted Losses (Estimated) = 1,997,880

Total Fixed Losses = 11,907,880 ÷ 3,412

$$= 3{,}490 \text{ KW}$$

4. CALCULATE HEAT LOSS TO FLUE GAS:

DATA:

Average Flue Gas Temperature =	1453°F
Average Combustion Air Temperature =	744°F
Average Waste Gas Temperature =	636°F
Average Outside Ambient Temperature =	15°F

Natural Gas Fuel Analysis Given by Greater Winnipeg Gas Company (1983):

CH_4	95.7%
C_2H_6	1.8%
N_2	2.2%
CO_2	0.3%
	100.0%

Trace only of Sulphur

ASSUMPTIONS:

1. Total combustion
2. Excess air = 10%
3. No SO_2 or CO formed during combustion

MOLES C AND H_2 per 100 MOLES OF FUEL:

		C	H_2
In CH_4		95.7	191.4
In C_2H_6		3.6	5.4
	TOTALS	99.3	196.8

Combustion calculation with reference to B&W's "Steam":

LINE	Fuel Constituent	Per Fuel Unit Lb.	MOL WT Divisor	Moles Fuel Constituent	O_2 Multiplier	O_2 Moles Theor. Req'd	CO_2 + SO_2	O_2	N_2	H_2O	CO
	Fuel, O_2 and Air Per Unit of Fuel						Flue Gas (F.G.) Composition Moles Per Fuel Unit (AF)				
1	C to CO_2		12	99.3	1	99.3	99.3				
2	H_2 to H_2O		2	196.8	.5	98.4				196.8	
3	N_2			2.2					2.2		
4	CO_2			0.3			0.3				
5	SUM			298.6		197.7					
6	O_2 (Theo.) Req'd					197.7					
7	O_2 (Excess) = $\frac{110-100}{100} \times O_2$ (Theo.)					19.8		19.8			
8	O_2 (Total) Supplied = Lines 6+7					217.5					
9	N_2 Supplied = 3.76 x O_2, Line 8					817.8			817.8		
10	Dry Air Supplied = O_2 + N_2					1,035.3					
11	H_2O in air estimated @ 1%					10.4				10.4	
12	Air (wet) supplied = Lines 10+11					1,045.7					
13	Flue gas constituent lines 1 to 12						99.6	19.8	820	207.2	
14	Total Flue Gas (wet)					1,146.6					
15	Total Flue Gas (dry)					939.4					

Determination of Flue Gas loss:

		CO_2	O_2	N_2	H_2O	Total
16.	Flue Gas Constituents					
17	MCP, Mean, T_2 to T_1, Refer to Fig.	10.2	7.3	7.05	8.25	
18	In dry flue gas = Line 13xMCPx(T_2 T_1)	630,900	89,800	3,590,000		4,310,700
19	In H_2O in air = Line 11xMCPx(t_2 T_1)				53,300	53,300
20	In Sens. Heat, H_2O in fuel = Line 2xMCPx (T_2-T_1)			1,008,300		1,008,300
21	In latent heat, H_2O fuel = Line 2x1040x18			3,684,100		3,684,100
22	Total in wet flue gas					9,056,400

23 Total Heat value of 100 Moles of Fuel
= 394 cu. ft./Mole x 987 BTU/Cu. Ft. x 100 Moles
= 38,887,800

24. Flue gas loss as pecentage of total heat
= $\frac{9,056,400 \times 100}{38,887,800}$
= 23.3%

25 23.3% of 21,464 KW = 5,001 KW.

5. SUMMARY:

Total Heat in Fuel			100%	21,464 KW
Heat in Steel	10109	47.1%		
Furnace Fixed Losses	3490	16.3%		
Flue Gas Loss	5001	23.3%		
Total Calculated Losses	18600	86.7%	86.7%	18,600 KW
Undetermined Losses			13.3%	2,864 KW

Undetermined Losses Include:

- Radiation losses from furnace recuperator, flue gas ductwork, waste gas ductwork, combustion air duct
- Dilution air
- Infiltration into flue

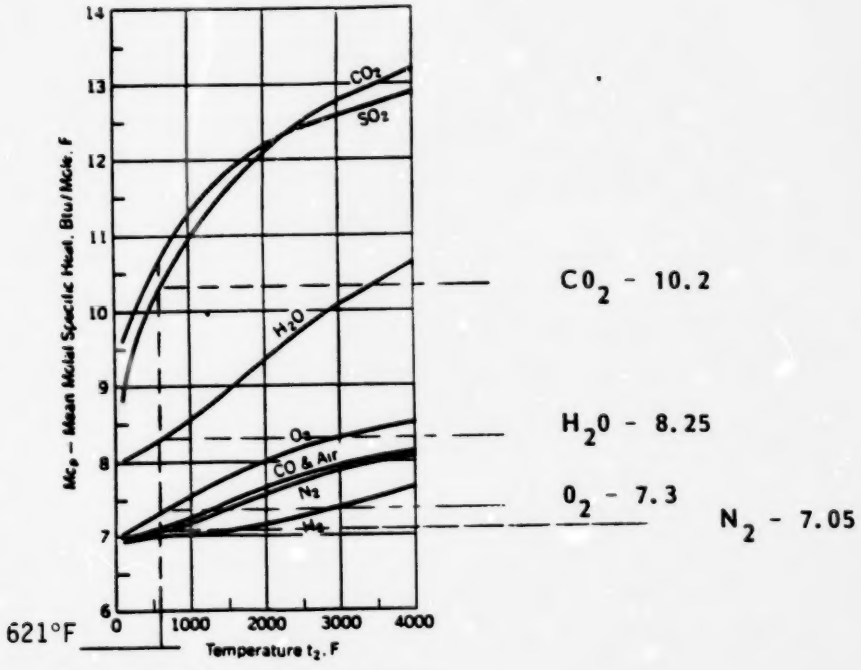


Fig. 2 Mean molal specific heat of gases between final temperature (t_2) and 80F at standard atmospheric pressure.